Indian J. Phys. **82** (5), 627-631 (2008)

Programmable trigger circuit for UHE cosmic ray detection by mini-array method : simulation with VHDL

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Abstract A trigger circuit (TC) to be used in the Mini Array Laboratory, Dept of Physics Gauhati University is designed using VHDL The Laboratory has been detecting Ultra High Energy Cosmic Ray (UHECR) Extensive Air Shower (EAS) for the last 16 years The working of the trigger circuit and its advantage over the already existing hardware is discussed in this paper

Keywords Ultra high energy Cosmic ray, Extensive air shower, Trigger circuit, Trigger pulse

PACS No. 29 40 Mc,29

1. Introduction

Studies of giant air showers produced by UHECR has gained importance due to the astrophysical aspects relating to GZK cutoff [1] and primary mass composition [2,3]. As the intensity of UHECR is very low, large ground based particle detector array is required for detection. For example, the AGASA detector array situated in Japan consisting of 111 particle detectors and 27 muon detectors covers an area of 100 sqkm, the Yakurtsk Array in U.S.S.R covers an area of 20sqkm and the Pierre Auger Project in Chicago consisting of Hybrid Ground based detector covers an area of 3000 sqkm. AGASA group has reported 57 events of energy (E) >4 x 10^{19}eV and 8 events with E > 10^{20}eV [4].Yakurtsk reported an air shower event with maximum E of (1.1±0.4) x 10^{20}eV [5]. Thus the possibility of detection of UHECR using Mini-array (small number of detectors with small carpet area) is totally removed. But Prof J Linsley proposed a novel method for detecting and analyzing UHECR measuring the thickness of shower front at large core

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distances by using a roof top Mini array [6-8].Based on this proposed method, a Mini-array has been set up in the Dept of Physics, Gauhati University, Assam to detect the UHECR[9]. This paper starts with a short description of the experimental set up used its limitations and finally simulates a circuit to overcome these difficulties using VHDL

2. The experimental setup of the mini array

The Mini array (MA) consists of 8 compact Plastic Scintillation Counters (size:50x50x5 cm^3) with a total carpet area of $2m^2$ placed inside a hut on the roof top of the Physics Building, Gauhati University, Assam [10] as in Figure 1.

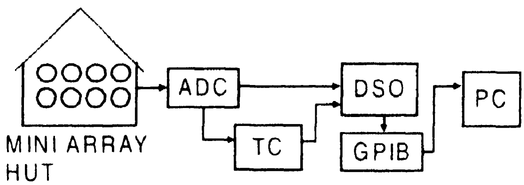

Figure 1. Block diagram of Mini-array set-up.

The pulses from the scintillation counters after passing through 8 discriminators with a lower discrimination level of 60mV(above the maximum noise level of the detector) is fed to the Digital Storage Oscilloscope (TEKTRONIX TDS 2022, 200 MHz, 2 GS/s) and recording is done in a PC *via* GPIB interface(GPIB-PCI NI-488.2). The recording starts by triggering the DSO by an external trigger circuit (TC) which produces a trigger pulse whenever a genuine UHECR EAS event occurs in the atmosphere. If there is a minimum of two particle pulses within a 2.5 μs time window, then the pulses are considered as generated by a genuine UHECR EAS event. Thus the TC first observes the total numbers of particle pulses within this stipulated time and whenever the minimum condition is satisfied

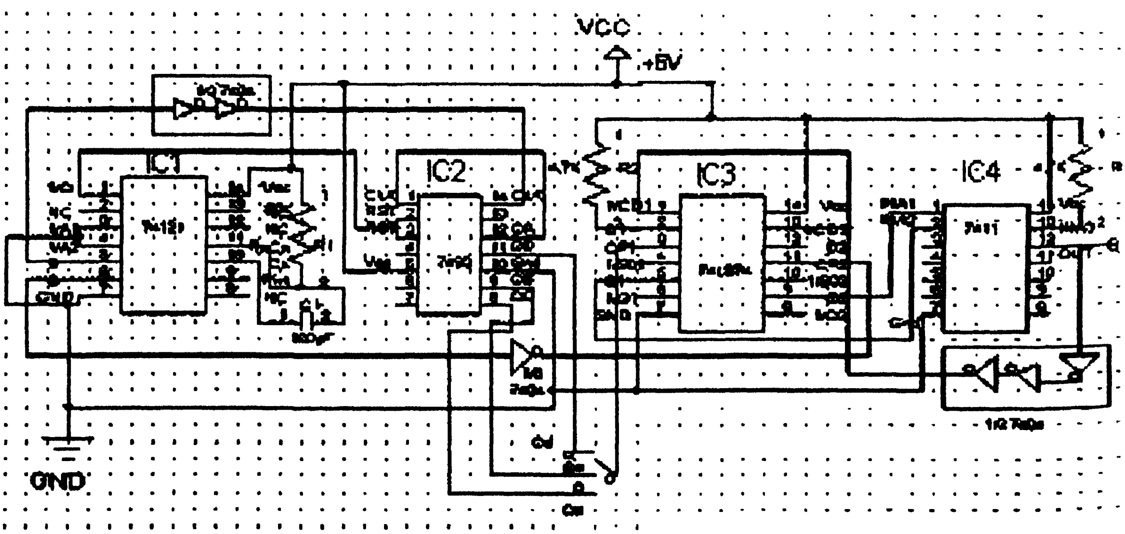

Figure 2. The trigger circuit.

it produces a trigger pulse of 30ns width to trigger the DSO. The total number as well as the arrival time difference of particle pulses within the time window are calculated off-line from the stored data, which corresponds to a particular energy of Primary Cosmic Ray at a particular core distance. Thus changing the triggering criterion *i.e* choosing the minimum number of particle pulses within the time window enables us to select different energies (within UHE range) of Primary Cosmic ray particles at a particular core distance[11].

3. The trigger circuit

The trigger circuit consisting of IC74121, IC7493, IC7474 ,IC7411 and IC7404 as shown in the Figure 2, is capable of producing trigger pulse for a minimum of 2,4 or 8 number of incoming pulses per stipulated time[12].

Two snap shots of the TC output using artificial pulses from a function generator is shown in Figure 3. It is therefore not possible to trigger the recording for a specific number of incoming pulses. Moreover the selection criterion for recording cannot be fixed for 3,5,6, 7 as the minimum number of incoming pulses offers a limitation to confining the recording process in terms of energy of Primary Cosmic Ray particle.

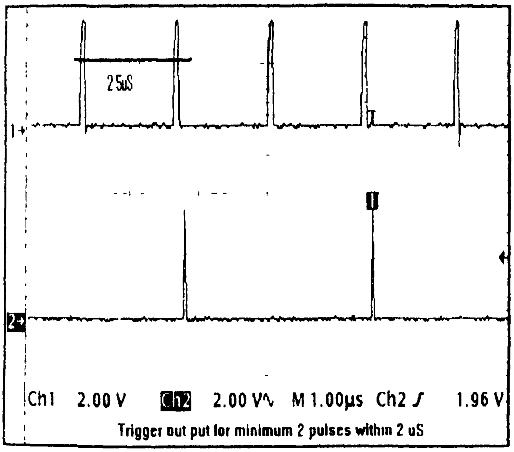

Figure 3(a). Trigger output for 2 particles

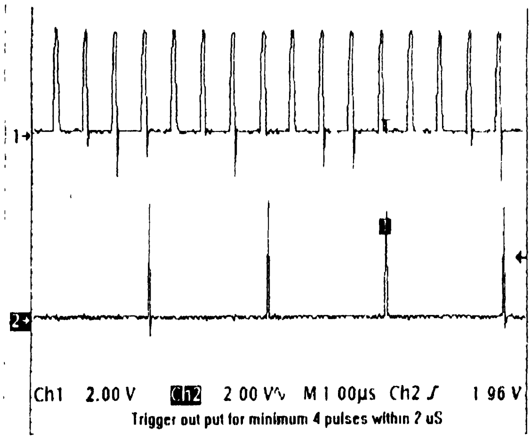

Figure 3(b). Trigger output for 4 particles

4. The Simulated Circuit using VHDL (Very high speed Integrated Circuit Hardware Description Language)

We model the new trigger circuit using VHDL (ModelSim SE 5.7g, evaluation version)[13] in the Top Level Behavioral Model.The block diagram of the model IC is shown in Figure

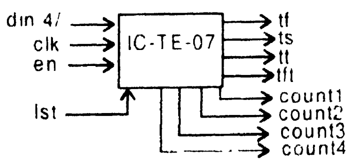

Figure 4. Block diagram of the simulated circuit

4. The clock frequency in this simulation is 10 MHz which is very high compared to the frequency of secondary UHE cosmic ray particle in the ground level.

The simulation is done only for 4 outputs corresponding to 4 input conditions. The 4 inputs is fixed at 2, 3, 4, 5 particle pulses within the 2.5 μs time window. Thus output 1 corresponds to the condition when there are only 2 particle pulses in the input, output 2 corresponds to 3 incoming pulses and so on. Thus by observing or selecting the outputs we can restrict our recording as desired. Moreover each output is connected with an up counter which counts the number of output pulses. One snapshot of the simulation is shown in Figure 5.

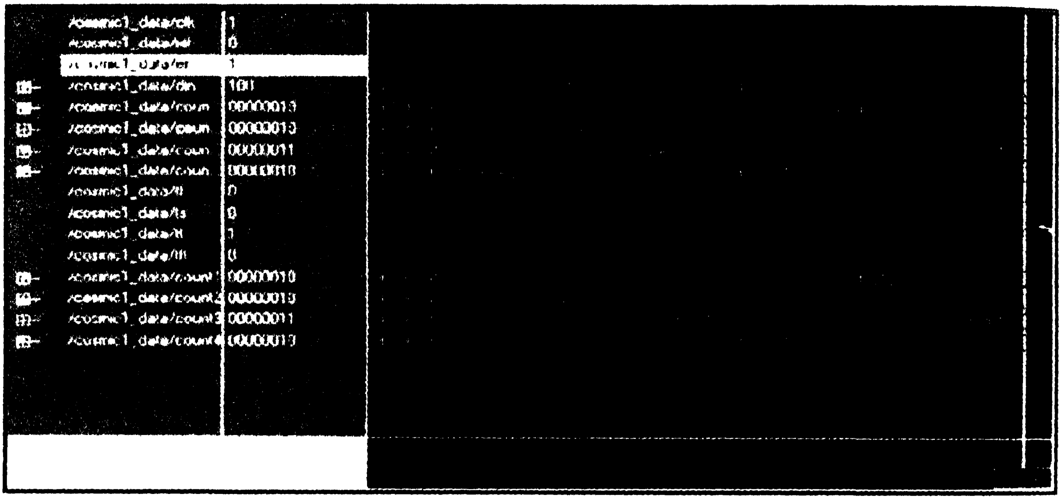

Figure 5. Snapshot of the simulated result.

5. Results and conclusion

A comparison of the existing and simulated TC (Table 1) shows that the latter has better triggering capabilities due to the fast rise and fall of the trigger pulse and offers a wide

Table 1. Comparison between the Existing and Simulated Trigger Circuit

Characteristics	Existing Trigger circuit	Simulated Trigger Circuit
Rise Time	10nS	8nS
Fall Time	14ns	5ns
Pulse Width	32ns	100ns
Selection Mode	2,4,8(min)	2,3,4,5
Trigger Pulse Counter	no	Up Counter
No.of output	no	Depending on On Selection Mode

range of selection criterions. Though here the pulse width is greater, there is no delay caused by the individual circuit elements. In our future work, we hope to implement this simulated circuit in FPGA (Field programmable gate array) or CPLD (Complex programmable logic device) and use it in the MA laboratory for precise studies on Cosmic Ray

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